SOME FACTS RELATIVE TO THE EFFECT OF HIGH FREQUENCY RADIO WAVES ON INSECT ACTIVITY*

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Lutz[1] has indicated that certain high frequency electro-magnetic waves were lethal to a cricket in one instance.

The writers were induced to begin a study of the effects of the gamut of wave lengths (characteristic of radio, infra-red, visible light, ultra-violet, x-ray and radium) by the mounting costs of the chemical control of insects and by the conception that various kinds of living tissue might well exhibit different normal wave lengths. Naturally the problem had to be attacked at some point and that was also naturally determined by apparatus available for producing vibrations. Through the courtesy of the General Electric Company a radio broadcasting apparatus giving a wave length of about 24 meters with a frequency of about 12,000,000 cycles per second was made available. These vibrations were produced through the agency of a 50 watt tube. An ammeter was installed in the line running to one of the terminals. The terminals consisted of two aluminium plates set facing each other. The energy shown on the ammeter could be varied by changing the distance between the terminal plates. The insects and substances experimented with were placed in small glass tubes suspended between the two aluminium plates but not in contact therewith.

The effect of high frequency waves upon the air in the tubes was first determined. The results of this study are set forth in table 1.

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1 Lutz, Frank E., Journal New York Entomological Society. No. 1, Volume 35, page 308, 1927.

TABLE 1

A STUDY OF INCREASE IN HEAT IN DIFFERENT PARTS OF GLASS TUBE USED FOR RESTRAINING HONEY BEES DURING EXPOSURE TO HIGH FREQUENCY

Position of Thermometer	Number of Runs	Av. Amps Used	Increase in Air Temperatures in Degrees F.	Time of Exposure in Minutes
Top quarter	3	1.72	2.8	5
Middle	3	1.74	3.5	5
One inch from bottom.	2	1.725	3.5	5
Bottom	3	1.703	3.0	5
Air between plates	2	1.77	2.5	5

Examination of table 1 serves to show that the increase in temperature in a five minute period does not exceed 3.5 degrees F. This examination also shows that the increase in air temperature between the plates in the absence of the glass tubes does not exceed 2.5 degrees F. Of course it is possible that the temperature recorded on the chemical thermometer is due to heat developed in the instrument and not in the air surrounding it but that contingency does not in any way interfere with the accuracy of the statement made above.

Having determined this factor various insects were introduced into the glass tubes and subjected to high frequency waves until they were dead. The results of this study are set forth in table 2.

TABLE 2

TIME REQUIRED FOR HIGH FREQUENCY WAVES TO PRODUCE DEATH OF CERTAIN INSECTS (ADULTS)

Insects Name	No.	Av. Amps	Av. Time in Minutes to Death	Date of Experiment
Apis millifera	49	1.8	1.28	12/1, 7, 1928
Apis millifera	45	1.78	0.996	12/19, 1928
Glypta	2	1.6	0.24	12/23, 1928
Hymenoptera			1.1	
Musca domestica	71	1.78	1.364	12/14–17, 1928
Diabrotica 12-punctata	12		2.056	10/19, 23, 24, 1928
Pieris rapae	4	1.6	2.08	10/22, 1928
Periplaneta germanica	87		2.23	12/1, 3, 4, 1928

Examination of this table serves to show that adult insects perish with decreasing speed in the following order: Hymenoptera, Diptera, Coleoptera, Lepidoptera, and Orthoptera. This order of difference in the effect of high frequency waves upon insects is interesting because of its apparent correlation with specialization in the morphological structure, especially as regards the nervous system. It would seem that the power of high frequency waves to affect insects varies more or less directly as the specialization of insect structure, particularly the nervous system. Time did not permit a thorough study of larval forms but it is known that much more time is required to kill such larvæ as have been tested than is required to kill adults.

It was observed that immediately after the insects had been killed through the application of high frequency their bodies were hot to touch. It was, therefore, logical that this condition should be investigated in view of the possibility that they might be perishing through the development of lethal high temperatures. The results of this study are set forth in table 3.

TABLE 3

A STUDY OF INTERNAL TEMPERATURES OF HONEY BEES WHEN ALIVE, WHEN RECENTLY KILLED BY HIGH FREQUENCY, AND WHEN KILLED 24 HOURS PREVIOUS TO TREATMENT WITH HIGH FREQUENCY

Number of Specimens Used	Av. Amps Used	Times in Minutes Alive	Internal Temperature Thoracic	Internal Temperature Abdominal	Time of Day When Test was Made
27	....	....	91.05	....	Morning
12	....	....	....	79.4	Morning
		Just killed with high frequency			
16	1.78	0.88	124.5	111.2	Morning
26	1.77	1.07	110.1	101.4	Afternoon
	Killed with HCN 24 Hours before exposure to high frequency				
15	1.79	1.25	103.3	....	Morning
20	1.73	1.25	101.9	....	Afternoon

Examination of this table serves to show that the normal internal temperature of living honey bees varies from 91.05 degrees F. in the thorax to 79.4 degrees F. in the abdomen. It also serves to show that immediately after the honey bee is killed with high frequency there exists a temperature in the thorax ranging from 110.1 to 124.5 degrees F. and in the abdomen a temperature ranging from 101.4 degrees F. to 111.2 degrees F. A curious difference appears between morning and afternoon studies. The writers can offer at this time no adequate explanation for this variation. Further examination of this table serves to show that an exposure of dead honey bees to high frequency for a period of one and one-fourth minutes fails to bring their temperature up to that which was obtained in the process of killing honey bees with high frequency.

Reflection upon the fact that high degrees of heat are developed in insects subjected to high frequency, while the air with which they are surrounded remains at a low temperature, indicates pretty definitely that subjection of insects to high frequency results in the development of a high internal temperature.

Reflection upon the facts—that the more highly developed the nervous system is the quicker the lethal heat is developed and that internal temperatures are developed more quickly in the living bee than in the dead bee when subjected to high frequency, lead to the general conclusion that the development of heat in the tissues is decidedly aided by nervous activity.

Naturally the next question is concerned with how this high internal heat is developed. The source of exciting energy is of course the high frequency wave. The tissues of the insect must react to this wave in such a way as to produce heat. To get some information of the reaction of different sorts of tissue to high frequency waves as measured in terms of temperature produced, a study was made of various chemical compounds characteristic of living matter particularly in the animal kingdom and the results are set forth in table 4.

Practically all of the compounds show some increase in temperature when subjected to high frequency waves. Of the sugars and starches glycogen stands out preeminently in that respect. Of the fats and oils cholesterol is revealed as still more powerful. Of the proteins peptone is high. Of the organic chemcal compounds in general, cholesterol is by far the most powerful and this fact is interesting when we realize that cholesterol is very commonly characteristic of nervous matter and activity.

TABLE 4

INCREASE IN HEAT ACCOMPANYING APPLICATION OF HIGH FREQUENCY TO VARIOUS CHEMICAL COMPOUNDS CHARACTERISTIC OF LIVING MATTER, PARTICULARLY IN THE ANIMAL KINGDOM

Compounds	Amps Used	Time of Exposure in Minutes	Increase in Temperature in Degrees F.	No. of runs
Sugars and starch				
Dextrose	1.80	5	71.5	2
Maltose	1.79	5	91.6	3
Levulose	1.80	5	23.12	5
Sucrose	1.82	5	23.25	2
Glycogen	1.80	1	73.0	1
Glycogen	1.80	5	128.0	1
Fats, oils, fatty acids and waxes				
Glycerine	1.80	5	5.5	2
Whale oil	1.775	5	7.6	4
Sperm oil	1.777	5	6.0	4
Linseed oil	1.793	5	10.16	3
Cetyl alcohol	1.795	5	42.75	4
Bees wax	1.800	5	8.5	3
Japan wax	1.835	5	18.5	3
Stearic acid (paste)	1.785	5	36.5	2
Stearic acid (barely wet)	1.78	5	58.6	3
Palmitic acid (barely wet)	1.800	5	67.4	4
Hog lard		5	11.2	2
Cholesterol (barely wet)	1.795	2.5	129.0	4
Cholesterol (dry)	1.800	5	0.0	1
Lecithin (barely wet)	1.800	5	69.5	2
Lecithin (gum like)	1.820	5	34.5	1
Proteins				
Casein (paste)	1.8	5	10.4	4
Casein (barely wet)	1.8	5	46.0	1
Pure protein (barely wet)	1.796	5	76.6	3
Egg albumen (barely wet)	1.8	5	9.0	1
Blood albumen (barely wet)	1.8	5	35.3	3
Harmoglobin (barely wet)	1.8	5	10.0	2
Peptone (barely wet)	1.775	5	113.5	2
Chitin (barely wet)	1.83	5	44.0	3
Charcoal (dry ground)	1.75	5	16.0	2
Charcoal (barely wet)	1.80	3	115.0	2
Charcoal (Allowed to stand two weeks with small amount of water	1.82	5	21.75	2
Silica (barely wet)	1.766	2	132.0	3
Quartz sand (barely wet)	1.80	5	122.5	3

Since carbon is the characteristic material present in organic compounds it was thought worthwhile to study its reaction in relation to high frequency as measured in terms of heat. This study reveals the high heating ability of carbon in the form of charcoal and a study of silica for the purpose of comparison reveals likewise that silica has a high heating reaction.

A study of table 4 serves to show that all the chemical compounds more or less characteristic of living animal tissue with which tests were made show decided increase in heat when subjected to high frequency and that of them all cholesterol stands out preeminently in that respect. It is also interesting to note in this connection that a small amount of water used in connection with these chemicals in a dry form greatly contributes to their heat productive characteristic.

Behind this phenomenon of heat production by living tissue and organic chemical compounds characteristic thereof there is doubtless a definite clear cut physical or physio-chemical explanation but the work of the writers has not proceeded far enough to enable them to see it.

Summary

1. Insects are killed when exposed to high frequency waves of 24 meters and 12,000,000 cycles per second with the ammeter reading about $1\frac{3}{4}$ amperes and this lethal effect is due to the development of an internal heat of lethal degree.

2. Nervous reaction speeds up the rate of producing this internal lethal heat and the more specialized the nervous tissue the greater is the increase in speed of reaction.

3. All organic chemical compounds with which the writers have worked and which are more or less characteristic of living tissue show ability to increase in internal heat when subjected to the above high frequency waves and of all of these organic compounds with which work has been done, cholesterol stands out preeminently in this respect.

4. Cholesterol is characteristic of nervous tissue.